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PREPARATION AND EVALUATION IN USE OF A SERIES OF BRIEF FILMS OF SELECTED DEMONSTRATIONS FROM THE INTRODUCTORY COLLEGE PHYSICS COURSE.

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AN ATTEMPT WAS MADE TO ASCERTAIN WHETHER MOTION PICTURE FILMS OF SELECTED PHYSICS DEMONSTRATION EXPERIMENTS WERE AS EFFECTIVE AS DEMONSTRATIONS PERFORMED DURING COLLEGE PHYSICS LECTURES. A SECOND OBJECTIVE WAS TO DETERMINE WHETHER STUDENTS WOULD TAKE ADVANTAGE OF THE OPPORTUNITY TO VIEW SOME EXPERIMENTS ON FILM OUTSIDE OF CLASS ON A VOLUNTARY BASIS. THE INDEPENDENT VARIABLES WERE THE FORMS OF INSTRUCTIONAL TREATMENT AND THE DISTANCE FROM WHICH THE STUDENTS VIEWED THE DEMONSTRATIONS. STUDENTS (393) WERE RANDOMLY ASSIGNED TO TWO CLASSES (LIVE DEMONSTRATION AND FILMED DEMONSTRATION) AND, WITHIN EACH CLASS, TWO GROUPS OF SEATS AT DIFFERENT DISTANCES FROM THE LECTURE TABLE. THE SAME QUIZZES AND EXAMINATIONS WERE GIVEN TO ALL STUDENTS. THE FILMED EXPERIMENTS WERE AS EFFECTIVE AS THE CONVENTIONAL METHOD, AND STUDENT ACHIEVEMENT IS INDEPENDENT OF THE DISTANCE (UP TO 60 FEET) BETWEEN THE STUDENT AND THE EXPERIMENT PRESENTATION. THE AUTHORS CONCLUDE THAT STUDENTS WILL VIEW EXPERIMENTS ON FILM OUTSIDE OF THE CLASSROOM WHEN THE MATERIAL IS AVAILABLE. (JC)

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I. PURPOSE OF THE STUDY

The major objective of this study was to ascertain whether motion picture films of selected physics demonstration experiments are as effective instructionally as demonstrations actually performed during physics lectures. A second objective was to determine whether students would take advantage of the opportunity to view some experiments on film outside of class on a completely voluntary basis. Also, it is hoped that the information in this report will answer some of the questions in the minds of college physics instructors about the use of films as teaching aids specifically in physics instruction.

Physics departments, particularly those in universities with large engineering schools, are confronted with a number of troublesome instructional problems which will become even more serious in the future. The fact that college enrollments are increasing rapidly and that the rate of growth also has increased sharply is well known. At the same time, enrollments in physics courses are increasing even more rapidly than general enrollments. This is due both to the necessity of placing more emphasis on fundamental mathematics and physical science in the training of future engineers, and to the growing awareness that physics is an essential part of the intellectual life of man.

The rate of increase of student enrollment has not been accompanied by a corresponding increase in the rate of acquisition of faculty. Even if the associated financial problems

could be overcome, qualified physics teachers are not available in numbers sufficient to maintain a proportional increase in faculty. This situation is further aggravated by the fact that an increasing percentage of faculty time is needed for advanced courses which are being created for the most able students.

It is evident that the ratio of students to teachers is rising and will have to rise still further in the future. In view of this, large group instruction will be used more than in the past, and it is necessary to learn ways in which large groups can be taught with increased effectiveness. As the transition from small group instruction to large group instruction takes place, it must be accomplished without seriously compromising instructional standards. For this reason, studies of the effectiveness of various kinds of teaching aids are of particular value at this time.

Although more large lecture rooms will be built, more efficient use must be made of existing rooms. Motion picture films can be of significant help for demonstration lectures to large groups. Since films can be used repeatedly, the problem of setting up and realigning apparatus between lectures is eliminated. This is particularly important when lectures are given in consecutive hours or are separated by hours during which other demonstration experiments must be shown. Availability of films of demonstrations which require appreciable preparation time will facilitate the continuous use of lecture rooms.

Although physicists have used visual aids for many years, these aids have been limited usually to experimental apparatus and lantern slides. Little interest has been shown in the use of instructional films, and practically no studies of the effects of their use have been made. A thorough search of literature reveals that the only reported investigations of instructional films for college physics were made by C. J. Lapp[1] about twenty years ago; by present day standards these studies exhibit serious shortcomings. R. L. Weber[2] has supplied three lists of instructional films for college physics but no evidence of instructional validity is given.

Perhaps the best summary of the attitudes of college physics instructors about the use of films was given by W. C. Kelly[3] in his remarks addressed to The International Conference on Physics Education held at the UNESCO House in Paris on July 18 to August 4, 1960. He says:

> What can we say about the use of films by the well-prepared, competent, interested physics teacher? My first observation - based on my own experience, broadened by many conversations with colleagues - is that the physicist in the university, or the secondary-school teacher of good physics education, uses teaching films rather seldom. Books command his attention, apparatus is something he enjoys constructing or buying and fussing over, but films for various reasons are peripheral to his teaching. The physicist uses films on rare occasions and seldom in a planned sequence.

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[1] C. J. Lapp, Am. Phys. Teacher 7, 172 (1939); ibid. 7, 224 (1939); Am. J. Phys. 8, 67 (1940); ibid. 9, 112 (1941)

[2] Robert L. Weber, Am. J. Phys. 17, 408 (1949); ibid. 22, 54 (1954); ibid. 29, 222 (1961)

[3] International Education in Physics, edited by Sanford C. Brown and Norman Clarke (Technology Press, Cambridge, Massachusetts and John Wiley & Sons, Inc., New York, 1960), pp. 106-111.

Later in the same discussion he remarks:

> Finally, some physicists have philosophical misgivings about films. Are they really better than demonstrations with real apparatus? Do students learn as well from them?

Kelly also makes another point:

> There is also a certain amount of unwillingness to change. Physicists have their ways of teaching. In the United States many foundations and other organizations have been concerned about the present shortage of qualified physics teachers and the greater shortage that is coming in the future; they have urged that new methods of teaching - using television and film and so on - should be investigated. But physicists tend to be very resistant to such suggestions.

The report presented here provides data from an instance in which films were prepared specifically for physics instruction and then evaluated in use in the classroom. It is our hope that this investigation will answer some of the questions in the minds of those who teach physics at the college level about the relative merits of the use of instructional films.

II. EXPERIMENTAL DESIGN

The introductory physics course for engineering students and physics majors at Purdue University consists of three one-semester parts, Physics 152, Physics 251, and Physics 262; these provide a total of fourteen credit hours. In each semester course, the student attends lectures given by staff of professorial rank, recitation classes taught by either professors or graduate teaching assistants, and laboratory sessions conducted by graduate students. This investigation is based upon the first course, Physics 152, which includes the study of mechanics and wave motion. The students in this

course are predominantly second-semester freshmen.

The instructional evaluation was designed to include two principal independent variables and to study their effects on student achievement. The first of the variables consisted of two forms of instructional treatment: (1) conventional, "live" demonstrations, and (2) filmed demonstrations. The second variable was the distance from which the students viewed the demonstrations; the two differently taught groups were seated in a 280-seat lecture hall in such a way that each student could be considered as a member of one of four "viewing distance" subgroups defined as the near quarter, medium-near quarter, medium-far quarter, and far quarter. The experimental evaluation was carried out during the spring semester of 1960, and again in the spring semester of 1961.

Physics 152 lectures are scheduled at 1:00 P.M., 3:00 P.M., and 4:00 P.M. on Mondays and Fridays, and at 10:00 A.M. on Tuesdays and Thursdays. The 3:00 P.M. and 4:00 P.M. classes on Mondays and Fridays were used as the experimental sections for the instructional film evaluation, while students from the other two sections were used in the investigation of the extent of use of optional, out-of-class viewing facilities. A discussion and analysis of the out-of-class viewing data is included in a later section of this report.

In scheduling, the 3:00 P.M. and the 4:00 P.M. sections of Physics 152 lecture were treated as if they were a single section with double the normal student capacity and a duration

of two periods, from 3:00 to 5:00 P.M. Thus, as Purdue's Datatron 205 computer scheduled students into the Physics 152 lecture sections, it had three alternatives: it could place students in the 10:00 A.M. class, the 1:00 P.M. class, or the 3:00 to 5:00 P.M. class. When registration was completed, about one-quarter of the students were in each of the first two sections, and about one-half in the last section. The existence of the double section made it possible to assign students randomly to treatment groups using the procedure described below. This randomization procedure provided some control on extraneous variables by establishing relatively equivalent groups for the different experimental treatments.

On the first day of classes, the students in the 3:00 to 5:00 P.M. section reported to a 1000-seat auditorium. As the students entered, IBM cards prepared with perforations of 3-digit random numbers were distributed in random order, one to each student. The student filled out this card with biographical data (name, address, school, major, class, previous semester's mathematics course and grade, and previous courses in physics) and then returned it, retaining a small stub for his own records. Students were assigned to either the 3:00 P.M. or the 4:00 P.M. section according to whether the first digit in the random number was odd or even, to the seats in the front or rear half of the lecture room according to whether the second digit was odd or even, and to seats in the front or rear of each of these halves according

to whether the third digit was odd or even. Notification of assignment was made by mail so that each student knew exactly where and when to report for the second meeting of the Physics 152 lecture class.

The two randomly constructed sections met for class in the same lecture room with the same instructor, Professor R. R. McLeod, and received the same instruction with the exception that the 3:00 P.M. section received conventional "live" demonstrations while the 4:00 P.M. section received the filmed demonstrations. The same procedure was followed in the replication of the experiment in the spring semester of 1961 except that the roles of the two sections were reversed, the filmed demonstrations being shown in the 3:00 P.M. section and live demonstrations being performed in the 4:00 P.M. section.

Of the thirty-two lecture periods available, six were used for examinations. Fifteen of the remaining twenty-six periods were used in the investigation reported here. A series of twenty filmed demonstrations was shown in these fifteen periods, there being two films per period in a few cases. A brief five-minute quiz was administered at the end of the lecture period to the students in each section on each day that films were shown. Also, one question of six on each of the five regularly scheduled hour examinations was used for this study. This question was designed to inquire about the principles of one or more of the demonstrations used in the previous three-week period. The purpose of this question was to allow a comparison of the treatment groups

in terms of retention of material to add to the data of the immediate recall comparison provided by the short quizzes.

The scores on all quizzes and examinations were included in the student's final grade in Physics 152, insuring that the student's performance would represent his best efforts. Examinations administered for the purpose of grade assignment are generally conceded to be an important criterion of student achievement even though they are often subject to adverse criticism. It should be pointed out that the test questions used here, while related to specific demonstrations, were not directed merely to discovering how well the student observed a demonstration, but rather to finding out if he understood the physical principles involved in and illustrated by the demonstration.

Analysis of the student scores was performed to test for the effects of: (1) the two different forms of instruction - filmed and "live", (2) the four different levels of viewing distance, and (3) interactions between these two independent variables. To accomplish this, three double classification analyses of covariance were made, using a pre-examination as covariate. In the first of these, the summed student scores on the fifteen short quizzes served as the dependent variable; in the second the summed student scores on the hour examination questions dealing with demonstration material served as the dependent variable; and in the third the summed student scores on the entire hour examinations were used.

The pre-examination used as covariate in the analyses of covariance provided a statistical control for differences among the students in previous knowledge of mechanics and wave motion, the content of Physics 152. The test, consisting of 40 multiple-choice questions, was developed specifically for this study and was administered to all students at the first meeting of the class. Its construction allowed students with no previous physics instruction to earn scores greater than zero (approximately 25 per cent of the questions could be answered from general knowledge of elementary science) while minimizing the probability of any student achieving a perfect score. Thus, a continuous scale of measurement of previous knowledge of the course content was provided.

Some notion of the equivalence of the experimental sections of students can be gained from inspection of the scores on this pre-examination. In the spring semester of 1960 the mean score of the students in the 3:00 P.M. section was 21.02, of those in the 4:00 P.M. section, 21.03. Corresponding figures for the spring semester of 1961 were 21.06 and 20.80. Further information about the scores on this pre-examination is given in Appendix A.

III. FILM PRODUCTION

About one hundred demonstration experiments are used in Physics 152 to illustrate the principles of mechanics and

wave motion. Most of the apparatus is simple enough and of sufficient size and painted with bright, contrasting colors so that it can be seen satisfactorily throughout the 280-seat lecture room. It was decided to use films to supplant live demonstrations in cases in which: (a) the apparatus is too small for details to be seen from all parts of a large lecture room, (b) the action to be demonstrated is too slow or too fast to be seen and adequately understood by the students, (c) the apparatus is so tedious to adjust in the short time between lectures that a successful execution is not consistently achieved, (d) so much time is required either for setting up and aligning the apparatus or for performing the experiment that it is sometimes necessary to shorten or omit the demonstration, (e) film techniques such as stop motion would strengthen the demonstration, or (f) more information might be conveyed with a film in the time allotted for a demonstration experiment.

It was originally planned to use some sequences from commercially available films if suitable ones could be found. However, after more than thirty films were examined without finding a single satisfactory sequence, the search was abandoned. There are relatively few good physics instructional films available, and it is almost impossible to find a film which is limited to illustrating one physical principle.

The twenty films used in this study were produced with the facilities of the Purdue Motion Picture Production Unit. This is an organization with a staff of five film production

men who act as producers, directors, cameramen, and sound technicians as required. Student assistants are available to help with routine jobs. Since its inception in 1954 the Purdue Unit has been instrumental in the production of more than 125 films sponsored by various academic, research, and extension agencies on the campus. Most normal film production services, except film processing and printing, are available. The equipment is of professional quality and includes six 16-mm cameras, various ones of which are equipped for synchronous sound, time-lapse, and single framing, an adequate number of lighting units, a title stand, both magnetic and optical sound recording and mixing equipment, and the usual editing facilities.

Like most university film production organizations the Purdue Unit is still growing and is not yet completely equipped. This imposed some limitations on what could be done. For example, only very simple animation could be used; further enrichment of some demonstrations could have been achieved if the proper sort of animation equipment had been available. Since most of the films previously produced by the Purdue Unit were in the fields of agriculture and the humanities, the limitations due to lack of animation equipment have been of little consequence. Our experience on this project has forcefully shown the need for such equipment and it is now being acquired.

Making an instructional film is not a simple task. Since this report will be read by physicists and others who might be considering film production projects, it is worthwhile to

describe some aspects of movie making. One might think that to make a film of a physics demonstration experiment, the physicist would perform the experiment in his usual manner and that the cameraman would perform the completely independent task of photographing the action. With several cameras it should be possible to obtain all the needed long shots and closeups at the same time. Narration to suit the action could be written later. In this way it should be possible to photograph several demonstrations in one day. Nothing is further from the truth. Film production is time-consuming work requiring much planning on the part of both the physicist and the film producer. To make a successful film requires that the film production staff must know just what the physicist is trying to register on film and that the physicist must understand both the capabilities and limitations of the camera and of film production techniques. A good film results only when there is complete cooperation and understanding on both sides.

Although producing a film is a complex process involving many compromises and improvisations along the way, a general description of the procedure may be given. First, all individuals involved in the project meet together to discuss the general ideas to be included in the film and then the physicists deliver a script to the film production staff. The latter, in conference with the physicists, examine the script in detail, deciding on camera angles, lighting, film footage for each scene, and other technical details, and then

invariably suggest changes in the script to include more close-ups and transition scenes.

After the script is rewritten the actual shooting begins. It is seldom that the scenes are photographed in sequence. Lighting the set to the satisfaction of the cameraman is a tedious procedure and the various scenes are usually shot in such an order that the number of lighting changes between scenes is held to a minimum. In general, it is not possible to make closeups and long shots at the same time, or even in succession, with the same lighting arrangement, since close-ups require more intense lighting than long shots.

The physicist must learn to be patient on the set; impatience and efforts to speed up the procedure often result in wasted time and film. Only by looking through the camera viewfinder can one appreciate the problems of the cameraman. It is not long until the physicist learns that the film production specialists have good reasons when they insist that the demonstration apparatus be placed in a different way from what the physicist has become accustomed to in the lecture room, or when they insist that for some manipulation the left hand should be used rather than the right hand, even though it may be awkward. The cameraman is doing his best to make every detail visible on the motion picture screen.

Another lesson the physicist must learn on the set is the necessity for retakes of entire scenes. If there is an error in a scene, even if it is in the last few seconds of a long scene, the entire action must be reshot. It is not

possible just to reshoot part of a scene and then splice it onto the satisfactory part. Such procedure would result in what is known as a "jump cut". It is impossible to rearrange all the objects on the set (including the hands of the demonstrator) in exactly the same position they occupied at the time of the trouble. If anything is displaced by as much as a quarter of an inch it will appear to jump on the screen. Furthermore, the cameraman often decides to take two or three shots of a single complicated scene to insure that at least one satisfactory take will be available when the film is edited, since film is cheap compared with the time and labor to duplicate the set and lighting at a later date.

Since physical conditions in the studio are quite different from those in a lecture room, systematic errors sometimes arise in a quantitative experiment when it is being photographed. For example, metallic parts of apparatus expand and photocells function improperly when subjected to strong illumination for long periods of time. Because of this, the physicists must analyze the data as the experiment proceeds to insure that the numerical results are internally consistent and acceptable within the limits of accuracy of the apparatus and the experiment. In some cases it is necessary to turn off the lights and wait for the apparatus to cool before proceeding with further measurements.

After the photography has been completed and the film has been sent to the laboratory for processing, the next step is to develop a sound track. Here again there is much

for the physicist to learn. There are two alternate procedures for making a sound film: either the visual portion of the film is made first and then an accompanying sound track is developed, or the script for the sound track is written in detail first and the length of the visual scenes is determined to fit. It is quickly apparent that the latter alternative is the easier of the two; the procedure actually used was a combination of the two methods.

It is a blow to the ego of the physicist when he finds that he is not the best man to narrate his own films. This blow is softened somewhat when auditions of several of his fellow physicists are also found to be unsatisfactory. Reading a prepared script is not the forte of the physics professor, but of the professional narrator. Of course, the latter must be carefully coached in pronunciation of words and expressions peculiar to physics, but once this is done the narration is usually recorded on magnetic tape smoothly and quickly. The physicist must stand by and listen carefully for mistakes so that corrections may be made immediately during the recording session. The voice quality of an individual changes from day to day and corrections in narration made at a later date can very seldom be matched satisfactorily.

The taped narration is used by the cameraman for timing while he photographs the charts, diagrams, graphs, equations, and so on (collectively described as "art work"). The film processing laboratory splices the live action and art work film together in random order and makes a copy to serve as

a workprint for editing. The workprint and the original film are run together through a machine which prints duplicate edge numbers on them so that any frame in the workprint can be located quickly in the original film. All editing is done with the workprint and a magnetic film copy of the narration tape recording. In general, the editing of the film is accomplished by the film production staff with practically no consultation with the physics staff. In a few cases where there are several satisfactory shots of an experimental measurement, the editor may call in the physicist to ask if he has a preference among them. The editor saves all footage that he does not assemble into the edited workprint. Only occasionally is it necessary to go back to the studio to make retakes of a particular scene.

After the editor has assembled the workprint according to the script, he arranges an approval session. This meeting is a very important one and it is attended by the entire film production staff as well as by all the physicists involved. The edited workprint is shown in synchronization with the sound track, on which the editor has mixed any required sound effects with the narration. The primary purpose of this meeting is to find any mistakes, whether they be the omission of a superscript in some equation in the art work, a flash frame the editor may have missed, a slip in synchronization between the visual and audio portions, and so on. But the approval sessions serve another very important purpose - it is here that physicist and the film production men come to a meeting of the minds, it is here that diverse points of

view are delineated, and it is here that compromises are made. After the approval session for the first film, our script writing improved markedly, and the direction, camera work and editing of the film production staff also improved.

The final step in the production of an instructional film is carried out by the editor alone. Using white gloves to handle the original film negative, he cuts it to conform exactly with the workprint version that has been approved. During the editing, he decides where to use the film processing technique of "dissolving" in which one scene fades out while another appears gradually to insure a smooth transition. Then he sends the original negative along with the sound track to the film processing laboratory. If it is anticipated that no more than a few prints will be needed, they are printed directly from the original negative; if more than five prints are to be made it is preferable to have the film processing laboratory make a duplicate negative from which to work, so that the original negative may be stored away as a valuable investment.

A series of twenty sound motion picture films was made for our evaluation study. A list of titles follows; pertinent information is included in parentheses:

Vernier and Micrometer Scales (b&w; 353 ft; 10 min)
The Laws of Sliding Friction (b&w; 217 ft; 6 min)
Hooke's Law and Young's Modulus (b&w; 325 ft; 9 min)
Galileo's Experiment on Constant Acceleration (b&w; 460 ft; 13 min)
A Measurement of the Speed of a Rifle Bullet (b&w; 154 ft; 4 min)
The Guinea and Feather Experiment (b&w; 138 ft; 4 min)
A Measurement of the Acceleration of Gravity: Falling Body (color; 274 ft; 8 min)

Galilean Relativity Demonstrated by Projectile Motion (b&w; 145 ft; 4 min)
Newton's Second Law of Motion (color; 310 ft; 9 min)
A Measurement of the Universal Gravitational Constant with the Cavendish Balance (color; 1200 ft; 33 min)
Independence of Horizontal and Vertical Motions (b&w; 120 ft; 3 min)
A Friction Brake Experiment (b&w; 225 ft; 6 min)
The Relation Between Impulse and Change of Momentum (color; 471 ft; 13 min)
An Experiment on the Conservation of Momentum (b&w; 302 ft; 9 min)
Elastic and Inelastic Collisions (color; 450 ft; 13 min)
Rotational Dynamics: Newton's Second Law (color; 660 ft; 18 min)
Rotational Dynamics: Kinetic Energy (color; 315 ft; 9 min)
A Measurement of the Acceleration of Gravity with Kater's Pendulum (b&w; 750 ft; 21 min)
The Speed of a Pulse in a Stretched Rope (b&w; 303 ft; 9 min)
A Demonstration of Interference of Waves with A Ripple Tank (color; 610 ft; 17 min)

It was planned to use magnetic recording for these films. To do this, the film processing laboratory affixes a stripe of magnetic oxide coating onto the finished print. Then the mixed narration and sound effects tape recording may be used to record on this strip. Magnetically striped film has the advantage that mistakes may be erased easily and corrected. Furthermore, the magnetic motion picture projector used for screening magnetic films is equipped with a recorder so that any instructor may erase the sound track on the film and substitute one of his own. Magnetically striped films offer great flexibility in the use of instructional films; for example, a film suitable for engineering physics students could also be used for a nontechnical physics course for students of the humanities by changing the narration. Unfortunately, the striping process is not yet tech-

nically perfect. The films used in the spring semester of 1960 were prepared with magnetic sound tracks. After repeated projection, portions of the magnetic oxide coating fell off, leaving disconcerting gaps in the sound tracks. Discussions with several film processing laboratories disclosed that this behavior is an all too common failing of this type of film - so much so, in fact, that a number of these laboratories have discontinued striping service. For this reason it was necessary to change to optical sound tracks for the film prints used in the replication of the evaluation study in the spring semester of 1961.

From the standpoint of the physicist, making instructional films in cooperation with university film production units rather than commercial film companies probably has more advantages than disadvantages. The chief disadvantage - the lack of some of the more expensive items of film production equipment - has been noted previously. Perhaps the major advantage for the physicists is the proximity of university film production facilities. Such close cooperation and communication between physicist and film producer is required that any distance of separation becomes an obstacle. Further, the physicist engaged in making films on his own campus remains in touch with familiar facilities - his own office and books, his own demonstration apparatus, and the advice of his colleagues.

Since university film production units are staffed with academically oriented personnel there is a singleness of

purpose among all working on the films, although the motives of the individuals may be somewhat different. The physicist is trying to prepare a good instructional film that he can use in his classes and which he hopes other physics instructors will also use; the film production specialist hopes to produce a film that is so effective in the classroom that other people may be persuaded to try making and using films in their courses. Excerpts of the series of twenty films have been used in various meetings on the Purdue campus to promote the use of audio-visual materials.

One obvious advantage of film production in university facilities is the low cost. It is well known that the cost of making instructional films in commercial facilities ranges from about $600 to $1000 per minute of running time. The cost for our series of twenty films was $106 per minute. Salaries of the physicists involved are not included in either figure.

To other physicists who may become interested in making instructional films, we would point out that such an endeavor is a worthwhile, challenging, and memorable experience and is just as much fun as other activities of physicists. It requires much more time than one would estimate; in this respect, film making is much like textbook writing. But the time is well spent and the sense of accomplishment that comes from seeing the finished product in use is ample reward.

IV. EVALUATION OF STUDENT ACHIEVEMENT

At the beginning of the 1960 spring semester 393 of the students enrolled in Physics 152 were assigned randomly to the two experimental lecture classes and to the four viewing distance groups according to the procedure described in Section II. During the semester 24 students withdrew from the course and so were eliminated from our study. These students were distributed fairly evenly over the eight treatment groups indicating that this loss of subjects was not related to the treatment combinations. The percentage of withdrawals was of the same magnitude as in previous administrations of the course.

The scores of the remaining 369 students on the pre-examination, the fifteen short quizzes, the five course examinations, and the five examination questions directed specifically to the demonstration lectures, were collected and treated in three analyses of covariance,[4] the results of which are summarized in Table I.

Using summed scores on the fifteen short quizzes as the dependent variable, the main effect of filmed demonstrations vs. actual demonstrations was found to be significant at the

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[4]See, for example, E. F. Lindquist, Design and Analysis of Experiments in Psychology and Education (Houghton Mifflin Company, Boston, 1953). For those unfamiliar with this statistical procedure, its merits in this instance are that it permits the isolation of that portion of the within-groups variability which is attributable to initial ability differences (as measured by pre-examination scores) in the groups. It is then possible to make corresponding adjustments in the dependent variable and to increase the precision of the F-test by removing the isolated variability from the error term.

TABLE I. SUMMARY OF ANALYSES OF COVARIANCE FOR THE 1960 STUDY

Dependent Variable	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Short quiz scores	Viewing distance (A)	1160.1658	3	386.7219	1.19
	Film vs. live (B)	2556.7001	1	2556.7001	7.90*
	Interaction (AXB)	829.2968	3	276.4323	.85
	Within groups (error)	116510.5222	360	323.6403	
	Total	121056.6849	367		
Examination scores	Viewing distance (A)	16852.2924	3	5617.4308	.95
	Film vs. live (B)	4676.4178	1	4676.4178	.79
	Interaction (AXB)	12130.8518	3	4043.6173	.69
	Within groups (error)	2119948.9056	360	5888.7470	
	Total	2153608.4676	367		
Examination special question scores	Viewing distance (A)	181.5702	3	60.5234	.43
	Film vs. live (B)	47.4458	1	47.4458	.34
	Interaction (AXB)	194.0501	3	64.6834	.46
	Within groups (error)	50902.5867	360	141.3961	
	Total	51325.6528	367		

* Significant at the .01 level

.01 level. Inspection of the initial and adjusted mean scores (total possible score = 175) of the instructional treatment groups in Table II indicates that the group of students who viewed the films achieved significantly higher scores, on the average, than the group of students in the conventional demonstration lecture. No significant differences were noted among the scores achieved by the groups of students at different distances from the lecture table. The interaction effect between these two variables was also found not to be significant.

As indicated in Table I, the results of the analyses using the summed scores on the hour examinations and the summed scores on the examination questions on principles of lecture demonstration experiments as the dependent variables show no significant differences among the treatment groups. Initial and adjusted mean scores, based on total possible scores of 500 and 75 for the examinations and the special questions respectively, are given in Tables III and IV.

Thus the data indicate that, on short quizzes administered at the end of the lecture hour, students in classes where filmed demonstration experiments were shown achieved higher scores than students in conventional lecture classes, regardless of the distance from the lecture table or movie screen. On the other hand, achievement in the two classes did not differ on questions asked at a later date or on general course examinations.

TABLE II. INITIAL AND ADJUSTED MEAN SCORES ON SHORT QUIZZES - 1960 STUDY

Viewing Distance Group	Film Group No.	Film Group Mean Scores Initial	Film Group Mean Scores Adjusted	Conventional Group No.	Conventional Group Mean Scores Initial	Conventional Group Mean Scores Adjusted	Total No.	Total Mean Scores Initial	Total Mean Scores Adjusted
Near $\frac{1}{4}$	47	100.70	101.28	47	93.64	93.25	94	97.17	97.27
Medium-near $\frac{1}{4}$	56	102.66	103.12	43	98.23	98.85	99	100.74	101.27
Medium-far $\frac{1}{4}$	45	102.76	102.39	47	101.11	101.61	92	101.92	101.99
Far $\frac{1}{4}$	45	104.98	103.99	39	96.54	95.92	84	101.06	100.24
Total	193	102.75	102.70	176	97.40	97.44	369	100.20	100.20

TABLE III. INITIAL AND ADJUSTED MEAN SCORES ON EXAMINATIONS - 1960 STUDY

Viewing Distance Group	Film Group			Conventional Group			Total		
		Mean Scores			Mean Scores			Mean Scores	
	No.	Initial	Adjusted	No.	Initial	Adjusted	No.	Initial	Adjusted
Near ¼	47	275.36	277.32	47	260.96	259.67	94	268.16	268.50
Medium-near ¼	56	268.34	269.88	43	264.02	266.08	99	266.46	268.23
Medium-far ¼	45	280.71	279.48	47	288.15	289.82	92	284.51	284.76
Far ¼	45	287.24	283.95	39	268.49	266.43	84	278.53	275.82
Total	193	277.34	277.21	176	270.64	270.79	369	274.15	274.15

TABLE IV. INITIAL AND ADJUSTED MEAN SCORES ON SPECIAL EXAMINATION QUESTIONS-1960 STUDY

Viewing Distance Group	Film Group			Conventional Group			Total		
		Mean Scores			Mean Scores			Mean Scores	
	No.	Initial	Adjusted	No.	Initial	Adjusted	No.	Initial	Adjusted
Near ¼	47	31.21	31.68	47	30.36	30.05	94	30.78	30.86
Medium-near ¼	56	31.11	31.47	43	30.00	30.49	99	30.63	31.04
Medium-far ¼	45	32.04	31.75	47	33.09	33.48	92	32.58	32.63
Far ¼	45	33.51	32.72	39	31.21	30.71	84	32.44	31.79
Total	193	31.91	31.88	176	31.19	31.22	369	31.57	31.57

When the experiment was repeated in the spring semester of 1961, a total of 560 students were assigned randomly to the two experimental classes. Because this group was much larger than that of the 1960 study, some students were assigned to overflow seats in the lecture room outside the established limits of the viewing distances. Data collected from these 66 students were not included in the analyses. In addition, 44 students withdrew from the course during the semester, so that the 1960 analyses were based on a sample of 450 students.

The results of the analyses of covariance using data obtained from the 1961 replication[5] of the experiment appear in Table V. No significant differences were found between the performances of the filmed demonstration and the live demonstration groups or among the four viewing distance groups, using any of the three dependent variables. No interaction effects between the independent variables were found to be significant. Initial and adjusted mean scores on each criterion variable are listed in Tables VI, VII, and VIII.

The significant difference in favor of the filmed demonstration group performance on short quizzes observed in the 1960 study was not found again. Results based on summed examination scores and summed scores on the special examination questions were similar to those noted in the

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[5]Because of an administrative decision to excuse most students from class on the day in which the last film was scheduled, the 1961 analysis is based on 14 quizzes.

TABLE V. SUMMARY OF ANALYSES OF COVARIANCE FOR THE 1961 STUDY

Dependent Variable	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Short quiz scores	Viewing distance (A)	250.0267	3	83.3422	.24
	Film vs. live (B)	17.3741	1	17.3741	.05
	Interaction (AXB)	1247.3390	3	415.7797	1.22
	Within groups (error)	150168.8658	441	340.5190	
	Total	151683.6056	448		
Examination scores	Viewing distance (A)	3718.9947	3	1239.6649	.25
	Film vs. live (B)	5566.7623	1	5566.7623	1.13
	Interaction (AXB)	8063.8317	3	2687.9439	.55
	Within groups (error)	2166211.1774	441	4912.0435	
	Total	2183560.7661	448		
Examination special question scores	Viewing distance (A)	80.2327	3	26.7442	.25
	Film vs. live (B)	18.1212	1	18.1212	.17
	Interaction (AXB)	370.7077	3	123.5692	1.15
	Within groups (error)	47252.7301	441	107.1490	
	Total	47721.7917	448		

TABLE VI. INITIAL AND ADJUSTED MEAN SCORES ON SHORT QUIZZES - 1961 STUDY

Viewing Distance Group	Film Group Mean Scores No.	Initial	Adjusted	Conventional Group Mean Scores No.	Initial	Adjusted	Total Mean Scores No.	Initial	Adjusted
Near ¼	58	100.81	99.74	56	99.70	100.02	114	100.26	99.88
Medium-near ¼	58	100.36	100.15	57	101.95	101.59	115	101.15	100.86
Medium-far ¼	53	99.11	98.62	56	100.55	101.32	109	99.85	100.01
Far ¼	55	100.58	101.77	57	95.86	95.77	112	98.18	98.72
Total	224	100.23	100.08	226	99.51	99.67	450	99.87	99.87

TABLE VII. INITIAL AND ADJUSTED MEAN SCORES ON EXAMINATIONS - 1961 STUDY

Viewing Distance Group	Film Group Mean Score No.	Initial	Adjusted	Conventional Group Mean Score No.	Initial	Adjusted	Total Mean Score No.	Initial	Adjusted
Near ¼	58	279.66	276.69	56	282.38	283.26	114	280.91	279.92
Medium-near ¼	58	273.83	273.23	57	290.32	289.33	115	281.57	281.21
Medium-far ¼	53	278.23	276.85	56	286.64	288.75	109	282.55	282.96
Far ¼	55	275.00	278.30	57	272.12	271.88	112	273.53	275.03
Total	224	276.67	276.23	226	282.85	283.28	450	279.77	279.77

TABLE VIII. INITIAL AND ADJUSTED MEAN SCORES ON SPECIAL EXAMINATION QUESTIONS-1961 STUDY

Viewing Distance Group	Film Group Mean Scores			Conventional Group Mean Scores			Total Mean Scores		
	No.	Initial	Adjusted	No.	Initial	Adjusted	No.	Initial	Adjusted
Near $\frac{1}{4}$	58	36.28	35.72	56	37.84	38.01	114	37.05	36.84
Medium-near $\frac{1}{4}$	58	35.66	35.54	57	37.74	37.55	115	36.69	36.54
Medium-far $\frac{1}{4}$	53	37.87	37.61	56	36.54	36.93	109	37.19	37.26
Far $\frac{1}{4}$	55	36.45	37.08	57	35.11	35.06	112	35.77	36.05
Total	224	36.58	36.45	226	36.80	36.88	450	36.67	36.67

1960 study.

Although the major purpose of these analyses was to determine the overall effectiveness of the physics demonstration films as compared to the conventional demonstrations, the experiment also provided an opportunity to compare each individual film with its conventional counterpart separately. These comparisons give additional information concerning the effectiveness of each individual film and the importance of the viewing distance variable for each film. Using individual quiz scores as the dependent variables, successive analyses of covariance were performed for each of the fifteen demonstrations of the 1960 study and for each of the fourteen demonstrations of the 1961 study. The results of these analyses appear in summary form in Appendix B.

V. VOLUNTARY STUDENT USE OF FILMS

An informal study was made to determine to what extent students would voluntarily use films outside of class. *Physics* 152 students in the lecture classes not participating in the film evaluation experiment were invited to view and study the films outside of class. It was clearly stated in the invitation that the films were versions of lecture demonstration experiments which they had already witnessed in class and that viewing activities were on a strictly voluntary basis.

To make film viewing as convenient as possible a room in the Physics Building easily accessible to students was

equipped with a projector and screen. A proctor was on duty 44 hours each week to operate the projector and to keep records of student attendance. Students from the classes participating in the film evaluation experiment were not permitted to come to this room.

Of the 418 students in the classes invited to use the viewing facilities in the spring semester of 1960, only 46 (11%) took advantage of the opportunity. Of these 46 students, 31 visited the viewing room only once. A total of 71 visits to the viewing room was recorded.

In the spring semester of 1961, there were 68 students (about 16% of the 435 eligible students) who chose to make use of the film-viewing privileges. Of this group, 46 students came to the viewing room only once, while 22 made more regular use of the facilities. A total of 240 films were projected during the 111 visits the students made in this semester. Figure 1, in which the number of visits per month of each year are plotted, shows that the greater number of visits occurred early in the semester.

The data collected in this study indicate that some students will voluntarily use films for out-of-class study. Although many of the students who did use the film-viewing facilities did so only once, some used them on a regular basis and studied most of the films in the series.

An attempt was made to determine whether certain characteristics of students who used the film-viewing facilities were different from those of students who did not take

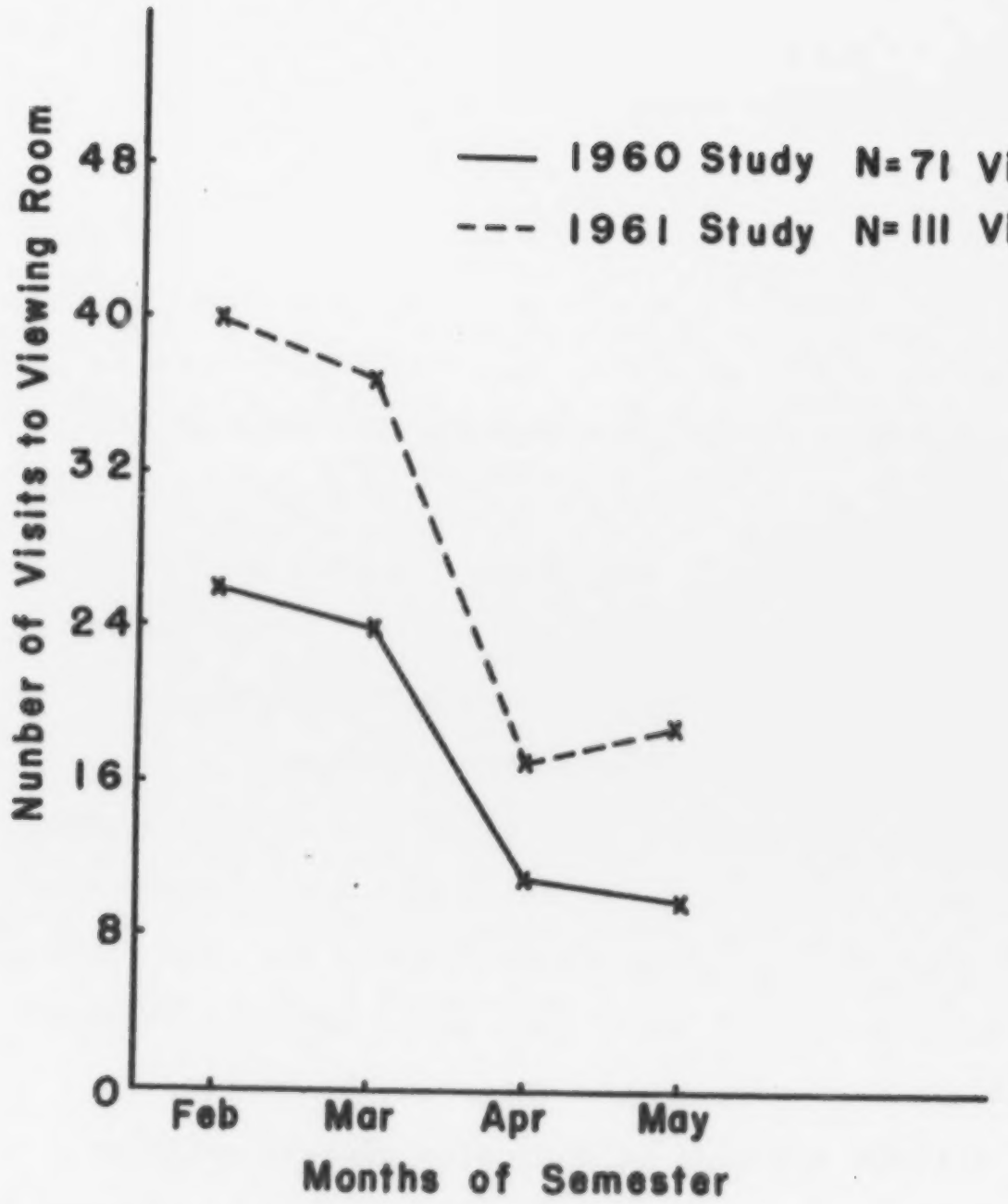
—— 1960 Study N=71 Visits
--- 1961 Study N=111 Visits
Number of Visits to Viewing Room
48
40
32
24
16
8
0
Feb
Mar
Apr
May
Months of Semester

Figure 1

TABLE IX. MEANS, STANDARD DEVIATIONS, AND t FOR THREE VARIABLES

Year of Study	Variable	Viewers			Non-Viewers			t
		No.	Mean	Standard Deviation	No.	Mean	Standard Deviation	
1960	Physics 152 Grade	46	3.67	1.37	359	3.42	1.16	1.40
	Cumulative Grade Point Average	46	4.40	.80	372	4.19	.68	1.92
	High School Rank	36	2.69	2.07	332	2.31	1.58	1.33
1961	Physics 152 Grade	66	4.00	1.14	366	3.92	1.22	.49
	Cumulative Grade Point Average	67	4.20	.64	368	4.22	.70	-.22
	High School Rank	63	2.21	1.30	366	2.17	1.47	.17

advantage of this opportunity. All available information about final grades in Physics 152, cumulative grade point averages at Purdue, and high school rank was collected. The means and standard deviations of these variables for the group of students who accepted the invitation to use the film-viewing facilities are shown in Table IX along with the corresponding values for the group who did not. The Physics 152 grades and the cumulative grade point averages are based on maximum possible values of 6.00. The high school rank is rated on a scale which extends from a high value of 1 down to 9. The means for the two groups have been compared statistically by the t-test.[6] No significant differences were found, indicating that these criterion variables do not serve to distinguish the students who used the films from those who did not.

VI. CONCLUSIONS AND DISCUSSION

Information gathered and analyzed in the course of this study support the following conclusions:

1. The presentation of lecture demonstration experiments by motion picture films is at least as effective, and perhaps more effective instructionally, than the conventional method of presentation.
2. Student achievement, as measured by short quizzes and course examinations, is independent of the distance

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[6] See, for example, E. F. Lindquist, op.cit.

(up to 60 feet) between the student and the lecture demonstration experiments. This statement is true irrespective of whether the experiments are performed by the lecturer or are presented on film.

3. Only a small fraction of the students voluntarily take advantage of the opportunity to study films which duplicate material previously presented in class, even when viewing facilities are made easily accessible and convenient to use. The students who do use this study aid are representative of all levels of ability and achievement, rather than being predominantly from one achievement level.
4. A few students voluntarily studied every film; presumably, they found films to be a valuable addition to their study.

The first of these conclusions is supported by the data and analyses presented in Tables I through VIII. Although only one significant difference in adjusted mean scores was found (in the case of the short quiz score in the 1960 study), there is a trend of higher mean scores for the group of students who saw the demonstrations on film. Moreover, the conditions imposed in this investigation were such as to minimize possible beneficial effects of the use of film. The method of presentation of the films was simple substitution for the lecture demonstration experiments. The lecturer made no introductory remarks before showing a film, nor did he

amplify or summarize the explanations of physical principles illustrated. No use was made of the opportunity provided by film to look at short, vital parts of the experiment several times without repeating the entire experiment.

In any learning experiment there are a number of extraneous factors which cannot be controlled completely. For example, the very knowledge that they are subjects of an experiment may have a deleterious effect on the performance of some students; the addition of short quizzes to the usual program of the course probably was resented by some students. Although problems of student dishonesty were present as in any course, the amount of cheating in this case was reduced by the presence of the abnormally large number of proctors required to minimize the time consumed by the mechanics of administering the quizzes and examinations. Contact between students of the two experimental classes in the short period between sessions was minimized by controlling the traffic flow so that students in the 3:00 P.M. section left the Physics Building through one door while the students of the 4:00 P.M. section were entering through another door. Every possible precaution was taken to remove other extraneous factors from this study.

The cause of the lack of agreement between the 1960 and 1961 results with respect to the short quiz variable is not known. Differences in the extraneous factors mentioned above were not observed during the experiment. The possible

effect of one other factor is worthy of speculation. It was noted by the entire instructional staff of Physics 152 that the class of the spring semester of 1960 contained noticeably fewer able students than did other classes of the past five years. Teaching by film may be more effective for less able students than for those of above average ability. Further research would be necessary to evaluate this possibility.

The second conclusion is an unexpected one. Through personal experience of observing demonstration lectures from the rear of the lecture hall, the lecturers know that some experimental apparatus is not clearly visible from this position. It might be expected that students seated in the rear of the hall should have more difficulty in learning from demonstration experiments than those near the front. The data of this study indicate that this effect does not exist to a significant extent. A tentative explanation of this finding might be that students learn well from blackboard diagrams and explanations of experiments and that the actual performance of the experiment is of secondary benefit. Another possible explanation is that in cases where students are told what to expect they think that they do see it even though they actually do not.

The third and fourth conclusions are not surprising. There are students who make much greater use of library facilities than do others, and so one would expect that there would be a group of students who would use a film

library if it were available. Since film libraries are relatively new and are a type of facility to which students have not had access previously in their academic careers, it is understandable that this group of students would be small. Experience in other courses indicates that after students have been required to view films or filmstrips as homework on a few occasions, they soon begin to use the film library just as they use book libraries.

Since these films have proved to be satisfactory instructional tools, the physics lecturers here at Purdue plan to continue their use. The conservation of time and effort previously spent in setting up and realigning the apparatus for these experiments will make it possible for the lecturers to devote time to other urgent tasks. Moreover, the lecturers believe that films in which such techniques as slow motion, stop motion, or time-lapse photography have been employed, certainly enhance the student's understanding of the physical principles illustrated. A set of these films will be available to students for individual study in the Purdue film library.

APPENDIX A. THE PRE-EXAMINATION

The pre-examination used as covariate has been described in Section II. Further information about it is given in this appendix. Reliability estimates are shown in Table X. Due to time limitations imposed by the course schedule it was not possible to administer this examination twice prior to the beginning of instruction so that the most appropriate method of estimating reliability could be used. Instead, two other methods of estimation have been substituted: a split-half reliability estimate based on a split by item analysis, and an estimate by the Kuder-Richardson formula #20. The coefficients determined by these estimates should be considered lower bound estimates.*

TABLE X. MEANS, STANDARD DEVIATIONS, AND RELIABILITY ESTIMATES FOR THE PRE-EXAMINATION

Year	No.	Mean	Standard Deviation	Kuder-Richardson #20 Reliability Estimates	Split-half Reliability Estimates
1960	369	21.12	3.97	.53	.39
1961	450	21.04	3.91	.51	.41

*A discussion of both methods may be found in J. P. Guilford, Psychometric Methods (McGraw-Hill Book Company, New York, 1954). A somewhat unique procedure was followed in obtaining the split-half reliability estimates. The examination items were divided into two equivalent half-examinations on the basis of item difficulty. The order in which the items appeared on the examination was not the exact order of difficulty.

Biographical data supplied by the students indicated that most of them had completed two semesters of physics in high school or elsewhere before enrolling in Physics 152. However, there was a group of students with either no previous physics courses or just one semester, and another group with three or more semesters. Average pre-examination scores for these two groups of students were computed, and comparisons of these means were made by using the t-statistic. The results are shown in Table XI.

TABLE XI. COMPARISON OF PERFORMANCE OF TWO GROUPS OF STUDENTS ON THE PRE-EXAMINATION

	Zero or One Semester Group			3 or More Semesters Group			
Year	No.	Mean	Standard Deviation	No.	Mean	Standard Deviation	t
1960	25	17.80	3.19	24	21.71	3.86	3.87*
1961	75	19.93	4.53	35	21.69	4.83	1.85

*Significant at the .01 level

APPENDIX B. ANALYSES OF INDIVIDUAL FILM QUIZZES

TABLE XII. RELATION OF FILMS TO SHORT QUIZZES

Title of Film	Quiz Number 1960	Quiz Number 1961
Vernier and Micrometer Scales	1	1
The Laws of Sliding Friction	2	2
A Measurement of the Speed of a Rifle Bullet	3	4
Galileo's Experiment on Constant Acceleration		
The Guinea and Feather Experiment	4	5
A Measurement of the Acceleration of Gravity: Falling Body		
Galilean Relativity Demonstrated by Projectile Motion	5	6
Newton's Second Law of Motion		
A Measurement of the Universal Gravitational Constant with the Cavendish Balance	6	7
Independence of Horizontal and Vertical Motions	7	8
A Friction Brake Experiment	8	9
The Relation between Impulse and Change of Momentum	9	10
An Experiment on the Conservation of Momentum		
Elastic and Inelastic Collisions	10	11
Rotational Dynamics: Newton's Second Law	11	12
Rotational Dynamics: Kinetic Energy		
Hooke's Law and Young's Modulus	12	3
A Measurement of the Acceleration of Gravity with Kater's Pendulum	13	13
The Speed of a Pulse in a Stretched Rope	14	14
A Demonstration of Interference of Waves with a Ripple Tank	15	15

TABLE XIII. UNADJUSTED MEAN SCORES ON INDIVIDUAL QUIZZES FOR THE FILM VS. LIVE AND VIEWING DISTANCE COMPARISONS IN THE 1960 STUDY

Dependent Variable	Film Group		Live Group		Viewing Distance: Near ¼		Med-near ¼		Med-far ¼		Far ¼	
	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
Quiz 1*	53.29	173	39.53	172	49.33	90	46.24	93	43.57	84	46.41	78
Quiz 2*	94.66	201	91.38	178	91.49	98	93.21	103	93.26	92	94.71	86
Quiz 3**	37.20	123	40.16	94	46.88	56	32.33	58	37.50	50	37.26	53
Quiz 4	60.77	188	58.33	168	55.23	86	61.25	100	62.37	93	59.09	77
Quiz 5	44.51	182	43.11	167	40.69	87	44.04	94	47.05	88	43.50	80
Quiz 6	81.06	191	78.31	175	80.17	92	80.35	99	79.92	93	78.33	82
Quiz 7	80.94	191	82.68	179	82.08	96	80.21	97	82.55	94	82.41	83
Quiz 8*	34.05	163	26.72	119	28.41	69	32.22	79	29.21	70	34.06	64
Quiz 9	57.65	179	58.13	166	58.37	86	59.57	92	55.96	89	57.56	78
Quiz 10*	63.91	179	71.64	165	69.41	85	67.05	95	67.29	85	66.71	79
Quiz 11***	58.61	183	53.72	161	53.62	85	53.99	92	61.24	86	56.58	81
Quiz 12	86.04	181	84.45	159	85.51	83	86.16	91	83.88	89	85.70	77
Quiz 13*	76.74	176	72.39	158	72.68	80	75.27	89	72.31	86	78.65	79
Quiz 14*	76.46	175	81.66	151	77.28	81	79.29	85	78.21	84	80.79	76
Quiz 15*	53.62	174	43.81	156	48.37	83	51.80	86	50.69	87	44.39	74

*Main effect of film vs. live demonstrations is significant at the .05 level
**Main effect of viewing distance is significant at the .05 level
***Both the main effect of film vs. live demonstrations and the interaction effect are significant at the .05 level

Note: All tests of significance were made using analysis of covariance procedures identical to those employed in the major analyses presented in this report. Complete analysis of covariance and adjusted means tables are available on request.

TABLE XIV. UNADJUSTED MEAN SCORES ON INDIVIDUAL QUIZZES FOR THE FILM VS. LIVE AND VIEWING DISTANCE COMPARISONS IN THE 1961 STUDY

Dependent Variable	Film Group		Live Group		Viewing Distance							
					Near ¼		Med-near ¼		Med-far ¼		Far ¼	
	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
Quiz 1	46.98	232	45.38	238	43.39	118	50.00	120	47.80	118	43.33	114
Quiz 2	92.65	232	90.68	233	91.82	116	91.43	118	92.43	116	90.97	115
Quiz 3	76.46	231	75.43	234	76.58	118	77.18	119	75.19	116	74.73	112
Quiz 4*	35.81	229	43.97	228	38.70	115	41.94	121	39.44	116	39.29	105
Quiz 5	45.23	228	45.45	226	46.53	114	43.56	115	44.61	114	46.72	111
Quiz 6	50.38	224	50.32	217	48.98	112	51.15	113	51.19	109	50.09	107
Quiz 7*	64.64	220	60.55	221	60.90	111	63.70	114	61.19	109	64.58	107
Quiz 8	77.67	227	77.84	213	77.24	116	77.60	112	77.83	106	78.40	106
Quiz 9*	22.76	217	29.43	216	27.25	113	25.28	113	24.55	105	27.25	102
Quiz 10	57.59	215	53.92	217	52.48	110	56.83	111	56.27	104	57.47	107
Quiz 11	66.58	225	64.98	221	66.09	115	65.44	114	64.63	108	66.97	109
Quiz 12*	53.15	212	64.75	203	59.52	104	56.42	108	62.05	104	57.34	99
Quiz 13	59.86	206	62.80	202	65.10	102	61.08	104	60.54	100	58.54	102
Quiz 14	80.89	202	80.05	203	81.52	105	80.10	102	80.59	101	79.59	97

*Main effect of film vs. live demonstrations is significant at the .05 level

Note: All tests of significance were made using analysis of covariance procedures identical to those employed in the major analyses presented in this report. Complete analysis of covariance and adjusted means tables are available on request.